U.S. Department of Energy
Energy Efficiency and Renewable Energy

Building Energy Modeling

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ENthPower Systems

Energy Modeling

- What is it?
- What can it do for me?
- The modeling process
  - Conceptual design
  - Schematic design
  - Design development
  - HVAC design options
- Cost - benefits

What is Energy Modeling

- Modeling is computer-based simulation
- Uses proven energy tools
  - DOE-2 energy assessment
  - Packages that use DOE-2
    - eQuest: Enhanced DOE-2 + Wizards + Graphics for larger buildings (free)
    - Energy-10: Similar to eQuest, Wizard based, Targeted to smaller buildings ($500)

What Can Energy Modeling Do For Me

- Save construction dollars
- Save operating dollars
- Improve occupant environment
- Required for LEED application

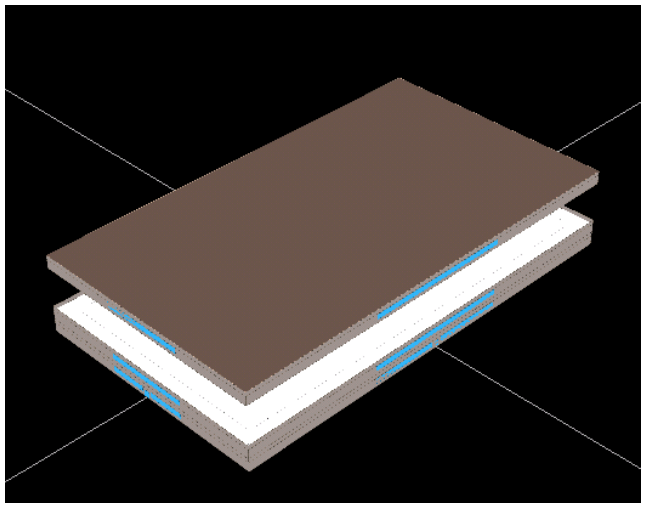
Conceptual Design Phase

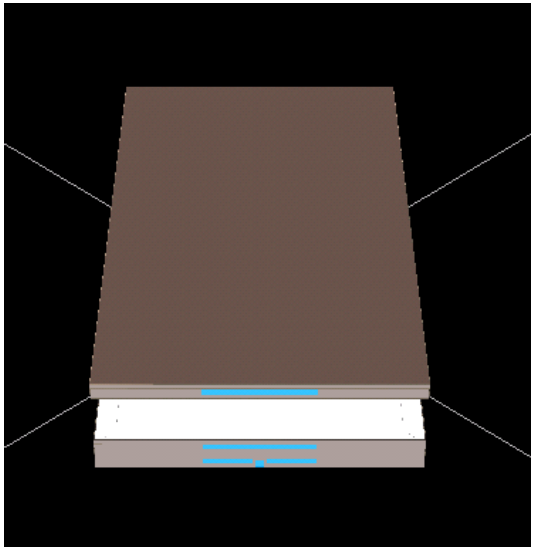
- Start with a simplified model of planned building
- Quickly test the:
  - Site location
  - Envelope materials
  - Building orientation
  - Number of stories
  - Glass area

Conceptual Design Phase

Site Location

- Rotate the building
  - Evaluate energy usage
  - Try different glass combinations
  - Use exterior shading





Envelope Materials

Annual Energy and Demand

		Ann. Source Energy		Annual Site Energy		Lighting	HVAC Energy	
		Total Mbtu	EUI kBtu/sf/yr	Elect kWh	Nat Gas Therms	Electric kWh	Electric kWh	Nat Gas Therms
Annual Energy USE or DEMAND								
0	Base Case	2,195	219	207,608	691	#Undef	56,133	691
1	0+Roof R-10	2,184	218	208,486	490		57,011	490
2	0+Roof R-15	2,180	218	208,973	400		57,497	400
3	0+Roof R-20	2,177	218	209,358	338		57,883	338
4	0+Roof R-25	2,176	218	209,778	282		58,302	282
5	0+Roof R-30	2,176	218	209,972	261		58,497	261
6	0+Wall R-10	2,189	219	208,169	579		56,693	579
7	0+Wall R-15	2,189	219	208,177	578		56,702	578
8	0+Wall R-20	2,187	219	208,445	529		56,970	529
9	0+Lighting 1 Wsf	1,826	183	168,254	1,029		48,755	1,029
10	0+Lighting 05 Wsf	1,649	165	148,883	1,247		45,372	1,247

		Annual Utility Cost				
		Electric kWh($)	Electric kW($)	Electric Total($)	Nat Gas Total($)	Total ($)
Annual COST						
0	Base Case	$ 12,872	$ 521	$ 13,513	$ 428	$ 13,941
1	0+Roof R-10	$ 12,926	$ 517	$ 13,563	$ 304	$ 13,867
2	0+Roof R-15	$ 12,956	$ 516	$ 13,592	$ 248	$ 13,840
3	0+Roof R-20	$ 12,980	$ 514	$ 13,614	$ 209	$ 13,823
4	0+Roof R-25	$ 13,006	$ 513	$ 13,640	$ 175	$ 13,815
5	0+Roof R-30	$ 13,018	$ 514	$ 13,652	$ 162	$ 13,814
6	0+Wall R-10	$ 12,906	$ 521	$ 13,547	$ 359	$ 13,906
7	0+Wall R-15	$ 12,907	$ 521	$ 13,548	$ 358	$ 13,906
8	0+Wall R-20	$ 12,924	$ 521	$ 13,564	$ 328	$ 13,892
9	0+Lighting 1 Wsf	$ 10,432	$ 430	$ 10,981	$ 638	$ 11,619
10	0+Lighting 05 Wsf	$ 9,231	$ 381	$ 9,732	$ 773	$ 10,505

eQuest Window Film Evaluation

Window Film

Project: Window Film Run I

Annual Energy and Demand

		Ann. Source Energy		Annual Site Energy		Lighting	HVAC Energy	
		Total Mbtu	EUI kBtu/sf/yr	Elect kWh	Nat Gas Therms	Electric kWh	Electric kWh	Nat Gas Therms
Annual Energy USE or DEMAND								
0	Base Design	1,189	118.90	91,724	2,496	45,994	27,215	2,359
1	0+Window Glass Type EEM	1,209	120.89	89,490	2,924	45,994	24,980	2,787

Project: Window Film

Annual Costs

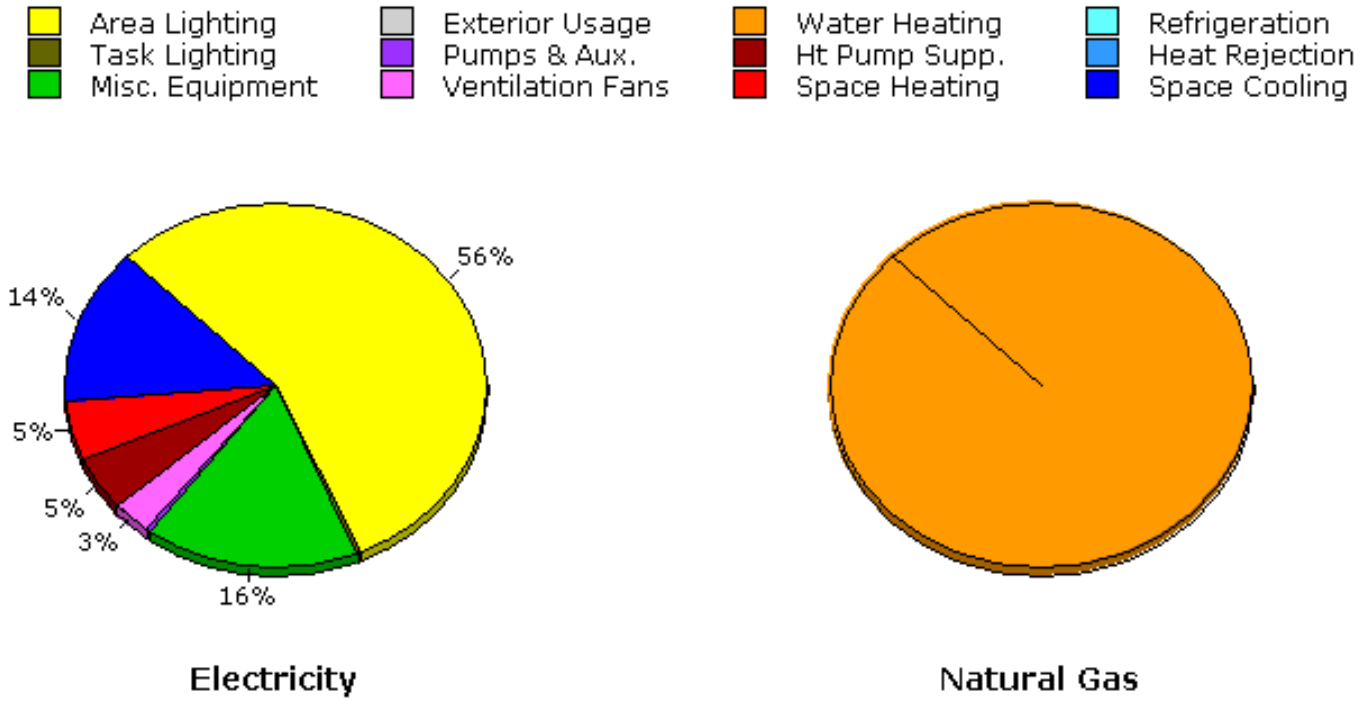
		Annual Utility Cost				
		Electric kWh($)	Electric kW($)	Electric Total($)	Nat Gas Total($)	Total ($)
Annual COST						
0	Base Design	$ 5,779	$ 443	$ 6,342	$ 1,547	$ 7,889
1	0+Window Glass Type EEM	$ 5,638	$ 424	$ 6,181	$ 1,813	$ 7,994

Schematic Design Phase

- Focus on most promising energy strategies
  - Fuel types and annual operating costs
  - Lighting alternatives like electronic dimming
  - Solar load impact on glazing choices
  - Daylighting opportunities
  - Window shading – interior/exterior

Utility Evaluation

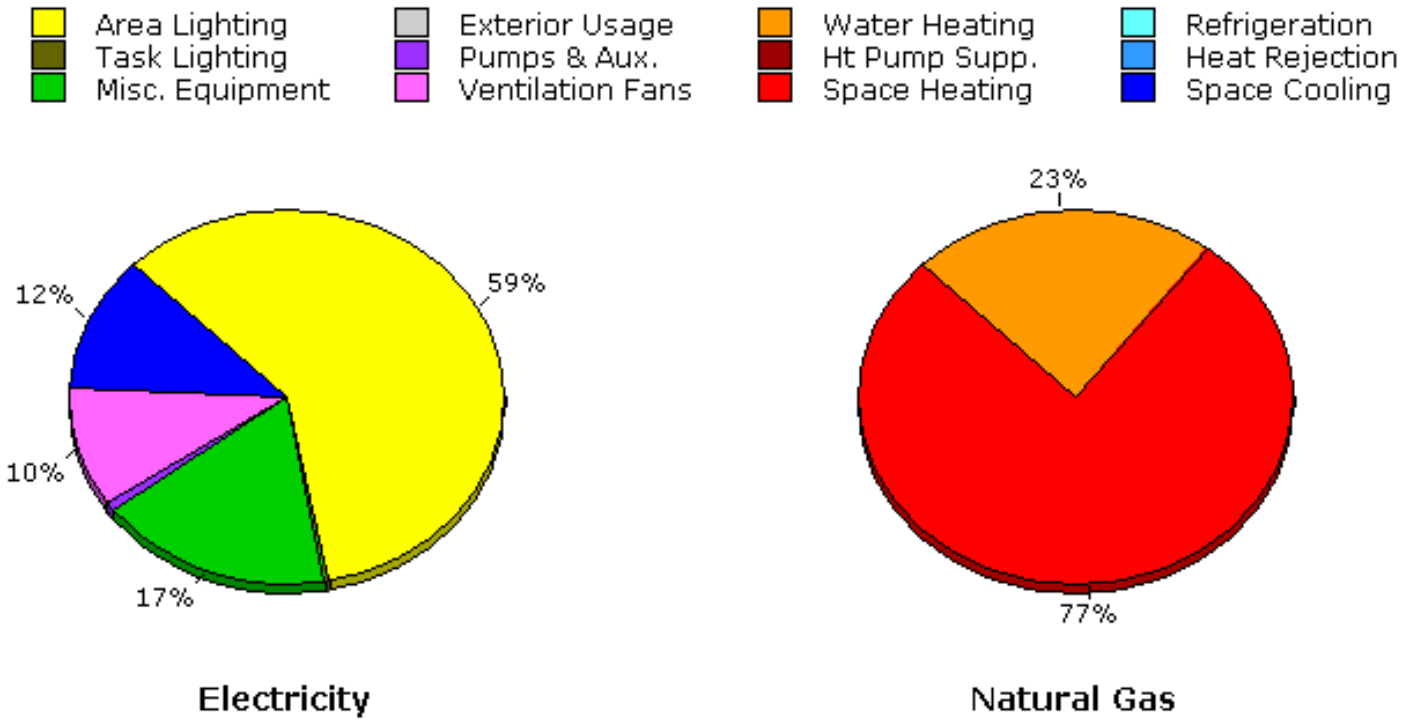
Fuel Types – Heat Pump



Air conditioning energy – about same. Gas used for domestic hot water only.

Utility Evaluation

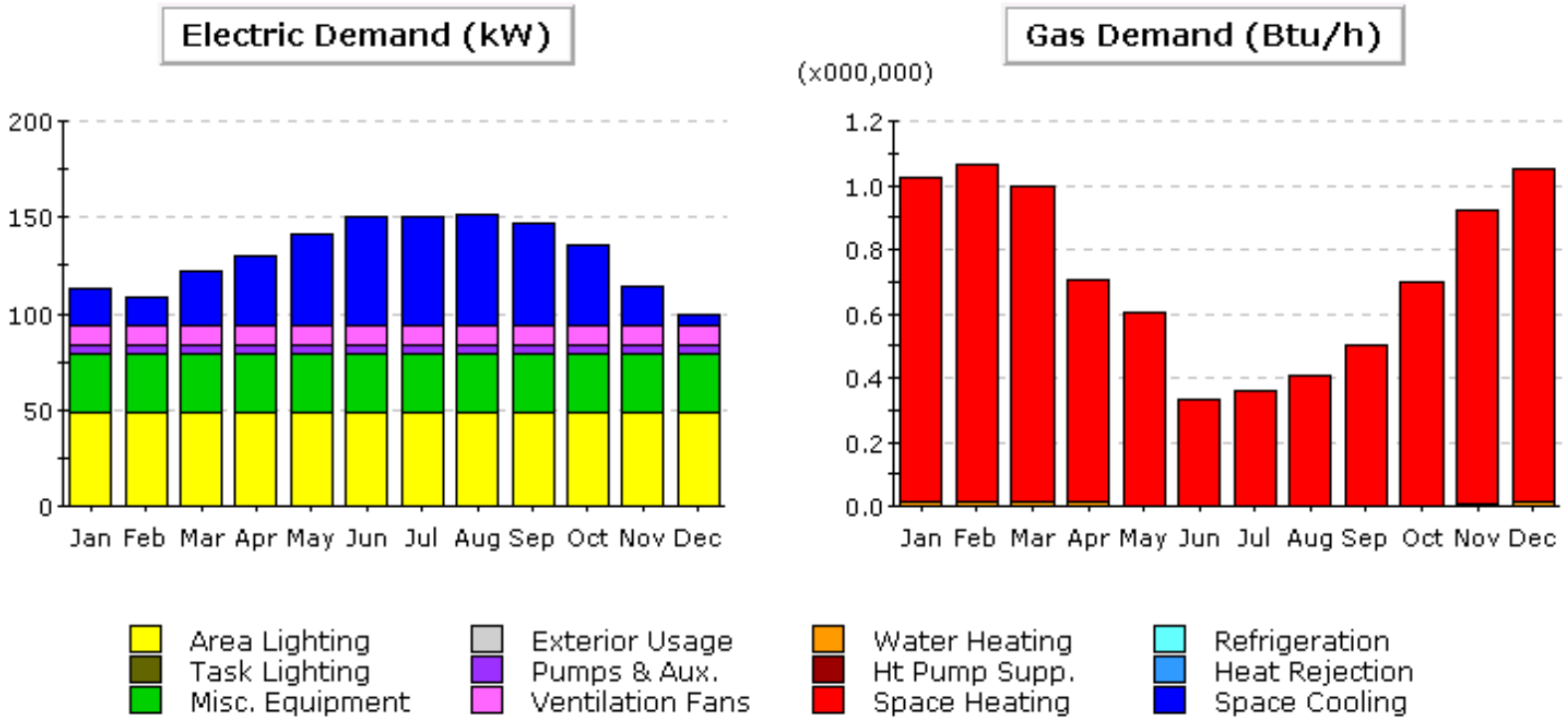
Fuel Types – Double Duct VAV

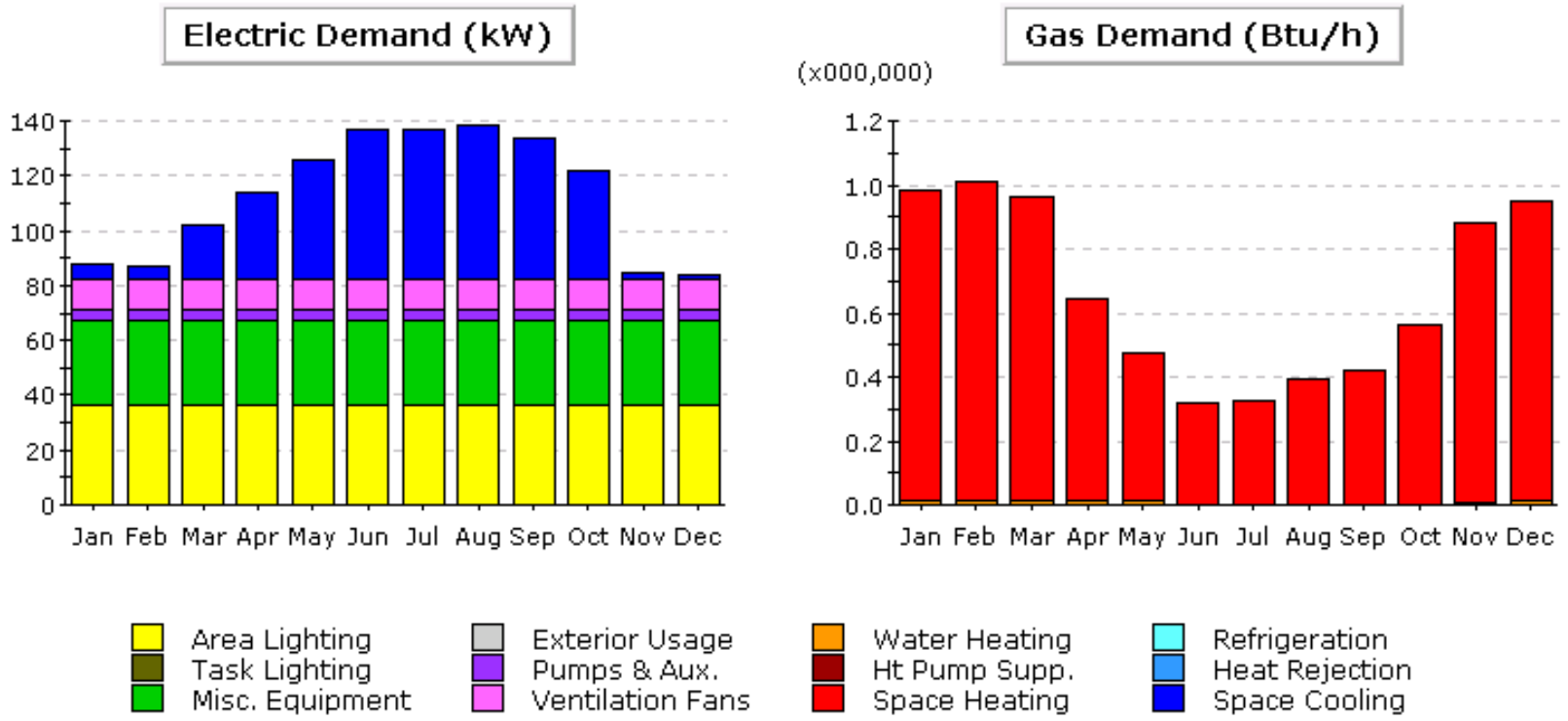


Air conditioning energy – about same. Gas primarily used for bldg heating.

Glazing Opportunities

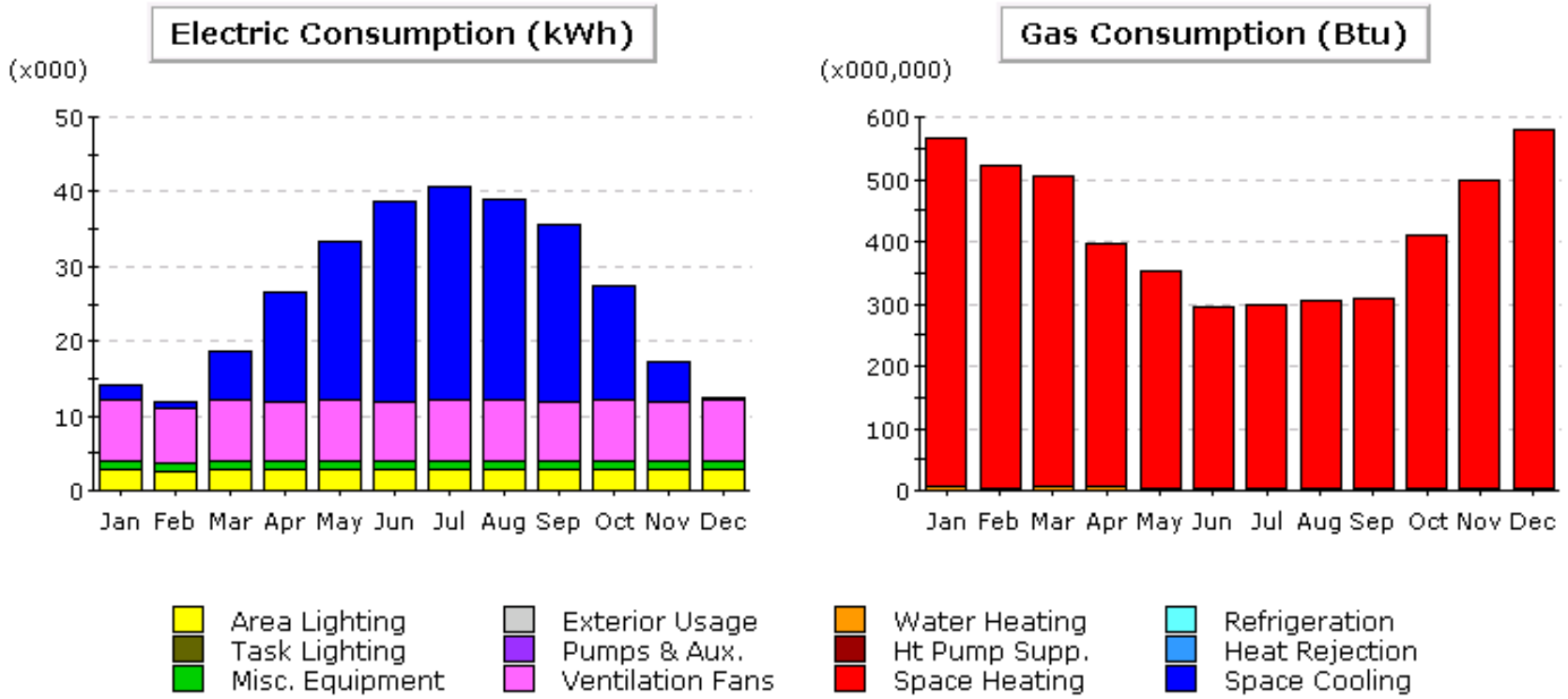
Minimum Windows




Electric Demand (kW)
140
120
100
80
60
40
20
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Gas Demand (Btu/h)
(x000,000)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Area Lighting
Task Lighting
Misc. Equipment
Exterior Usage
Pumps & Aux.
Ventilation Fans
Water Heating
Ht Pump Supp.
Space Heating
Refrigeration
Heat Rejection
Space Cooling

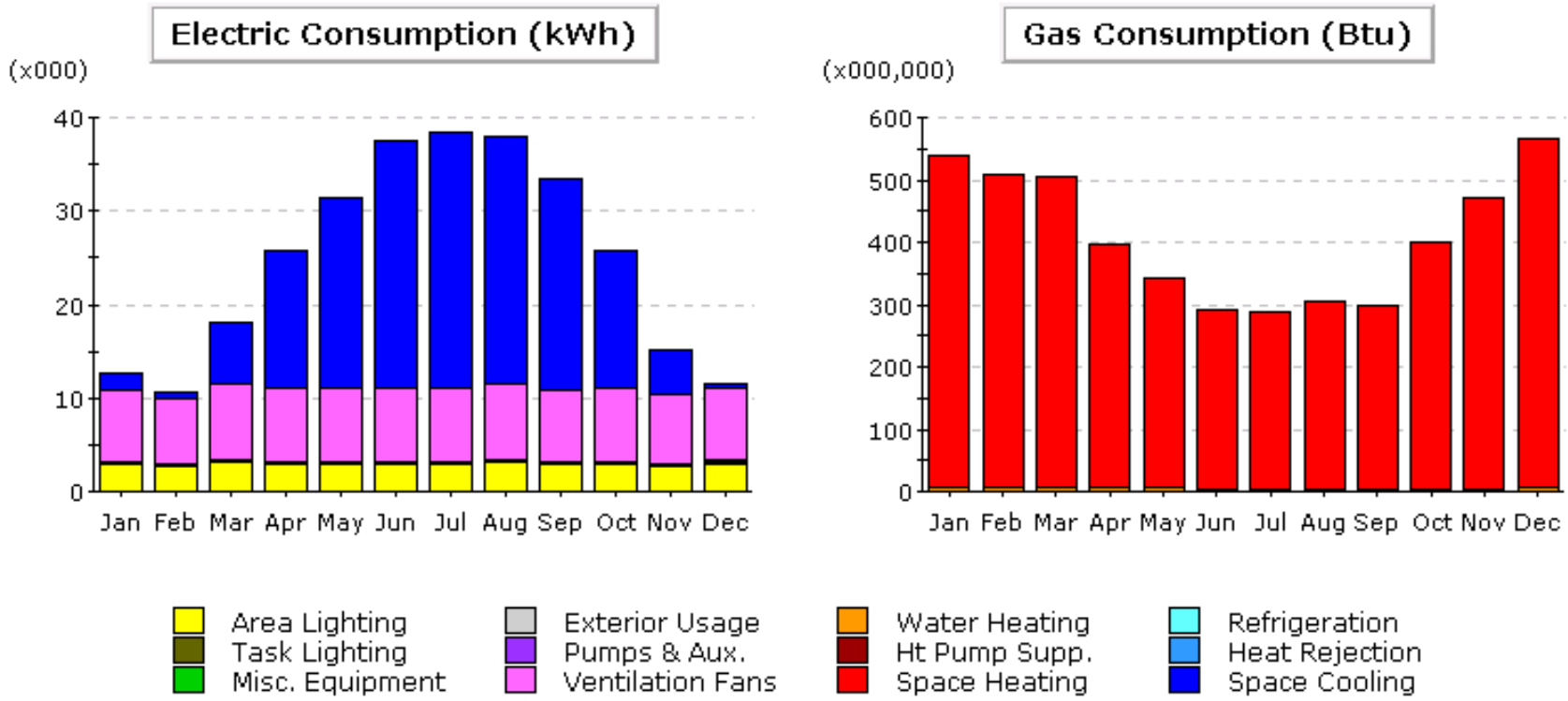
Daylighting Options

Conventional Design



Daylighting Options

Skylight Addition



Air conditioning energy went down and so did gas usage.

Design Development Phase

- Use parametric elimination techniques
  - Better understand construction energy use
  - Systematically eliminate choices
  - Try alternatives:
    - Vary the type and quantity of glass
    - Change the wall and roof insulation thickness
    - Re-orient the building on the site
    - Change the HVAC system types

HVAC Design Options

- Critical Choices
  - Type of HVAC system
  - Ease of maintenance
  - Environmental factors
  - Interior comfort
  - Humidity control
  - Site suitability (remodel limitations…)

HVAC System Analysis

Level I – Ranking Possible Systems

Strategic Checklist	POTENTIAL SYSTEM TYPES						
	Scoring Range	**Scoring Wghtng**	**System #1** (i.e. VAV)	**System #2** (i.e. VAV Reheat)	**System #3** (i.e. Water Source Heat Pump)	**System #4** (i.e. Geothermal Source Heat Pump)	**System #5** (i.e. 4-pipe Unit Vents)
Achieves EPA EnergyStar Target	1-5	1					
Annual Energy Usage ($/sf)	1-5	5					
First Costs (Total Installed in $/sf)	1-5	2					
Maintenance Costs ($/yr)	1-5	1					
Ease of System Maintenance	1-5	2					
Maximizes Indoor Air Quality Control	1-5	5					
Manages Effective Humidity Control	1-5	5					
Site Suitability (physical limitations, staging, etc)	1-5	1					
Zonability	1-5	1					

Consulting engineer sets scoring range. Client sets scoring weight.

HVAC System Analysis

Level II – Detailed Analysis

Re-evaluation of Level 1 criteria

Re-evaluation of Level I criteria	SYSTEM TYPES				
	Scoring Range	Scoring Wghtng	System #1 (i.e. VAV)	System #2 (i.e. HP)	System #3 (i.e. Unit Vent)
Achieves EPA EnergyStar Target	1-5	1			
Ease of System Maintenance	1-5	2			
Maximizes Indoor Air Quality Control	1-5	5			
Manages Humidity Control	1-5	5			
Site Suitability (physical limitations, etc)	1-5	1			
Zonability	1-5	1			

Consulting engineer sets scoring range. Client sets scoring weight.

Other Evaluation Parameters

HVAC System Analysis

Level II – Detailed Analysis

Additional Level II Criteria

Additional Level II criteria	Scoring Range	Scoring Wghtng	System #1 (i.e. VAV)	System #2 (i.e. HP)	System #3 (i.e. Unit Vent)
Capability for Individual Space Control	1-5	3			
Floor Space Required	1-5	1			
Complexity/Quantity of Equipment	1-5	1			
Component Life Expectancy	1-5	1			
Noise Factor	1-5	1			
Ability to Achieve Desired Control Points	1-5	2			
SUBTOTAL					
GRAND TOTAL					

Consulting engineer sets scoring range. Client sets scoring weight.

Sample HVAC Options

To Reduce Building Energy

IDENTIFY HVAC OPTIONS THAT WILL BE CONSIDERED TO REDUCE BUILDING ENERGY LOADS			
	Exhaust air heat recovery		Night purge
	Plate and frame free cooling		Optimum start/stop
	Strainer-cycle free cooling		Load shedding economizer
	Decoupler systems		Night sky radiant/evap cooling
	Parallel chiller sequencing		Thermal fusers
	Low temperature air		Low face-velocity air handlers
	Airside economizer		Double-bundle heat recovery
	Refrig. Migration free cooling		Thermal storage
	Hot gas reheat		Dessicant systems
	Series chiller sequencing		Heat Recovery Chillers
	Chilled water reset		Condensing Boilers
	Fan cycling		Geothermal Cooling
	Duty cycling		Discharge Air Reset

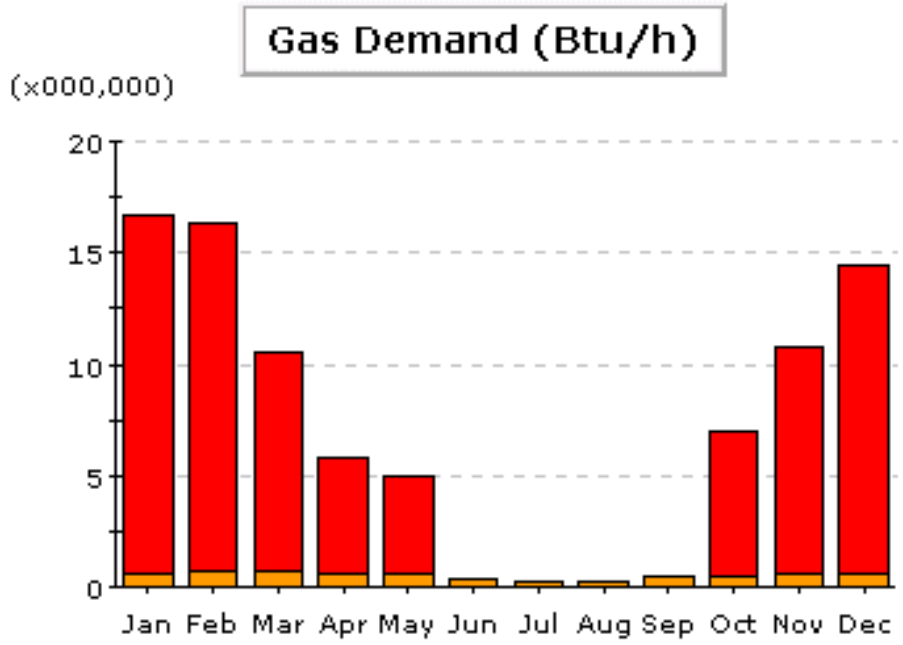
Elementary School

Example HVAC Evaluation

Type	Air	Annual Kwh x 1000	Annual Gas Mbtu	Tons	Annual Kwh $	Annual Gas $	Total $	Comp	Btu/SF Comp
DDVAV	Double Duct VAV w/core Reheat	684	1,872	313	$63,128	$14,046	**$77,174**	37%	96%
VAVReheat	Single Duct VAV w/Reheat (140 Max LWT)	591	170	276	$55,747	$1,275	**$57,022**	1%	2%
VAVReheat-1	Single Duct VAV w/Reheat (180 Max LWT)	590	135	283	$55,174	$1,019	**$56,193**	**Low**	Low
FCUHWCHW	4-Pipe Fan Coils & VAV AHU w/Reheat	616	267	294	$55,737	$2,008	**$57,745**	3%	10%
FPVAV	Fan Powered VAV Boxes throughout	973	117	266	$78,485	$883	**$79,368**	41%	60%
FPVAV Perim	FP VAV Boxes Perimeter w VAV/Reheat Core	979	523	284	$79,098	$3,924	**$83,022**	**48%**	80%
HP - RED	Water Source Heat Pumps	624	754	265	$66,192	$5,659	**$71,851**	28%	34%
HP - MRL	Water Source Heat Pumps	637	30	232	$61,127	$225	**$61,352**	9%	3%

Example Boiler Evaluation

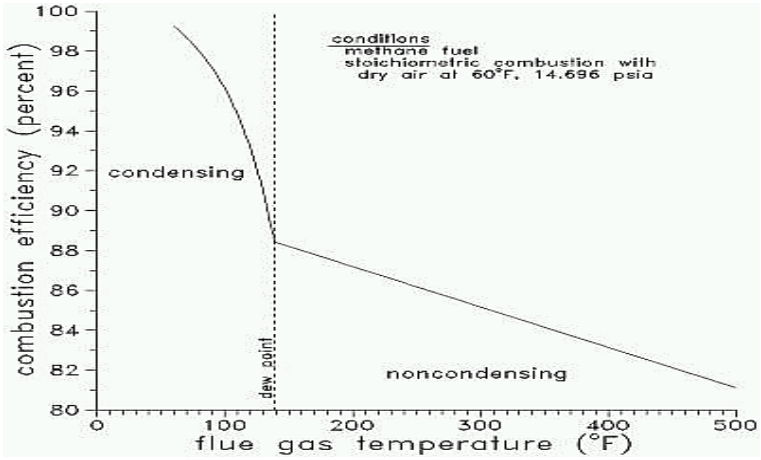
- How many high efficiency boilers are needed?
- Situation: Peak Htg Demand
  Max = 17 MBtus,
  Min = 5 MBtus



From eQuest energy model

Boiler Efficiency

- Condensing boilers are very efficient at low temperatures
- Question: what is the optimum number of boilers considering the efficiency factors of condensing boilers?



Boiler Efficiency Evaluation

Situation: retain one existing boiler and add *how many* Aercos and *how large* should the base load boiler be?

					Number Aerco	# Aercos w/ Base Load	# Aercos w/ Base Load
Time of Day	Total Heating MBtu	OA Load	Total Htg Load	90% Boiler Eff.	Only Boilers	Boiler = 6000 MBtu In	Boiler = 8000 MBtu In
8:00	11054	1742	12796	14218	8	5	4
9:00	9637	1742	11379	12643	7	4	3
10:00	6454	1742	8196	9107	5	2	1
11:00	5682	1742	7424	8249	5	2	1
12:00	4957	1742	6699	7443	5	2	1
13:00	4591	1742	6333	7037	4	1	1
14:00	4011	1742	5753	6392	4	1	1
15:00	3416	1742	5158	5731	4	1	1

What Really Determines Energy Usage?

- Equipment Runtime - *Overwhelmingly important!*
- Reheating for Humidity Control - *Real killer*
- Outside Air Ventilation - *Runtime and heat reclaim dependent*
- Night Setback - *Must enforce*
- Lighting On-time - *Use occupancy sensors*
- Air Delivery Quantity – *Use occupancy sensors with computer-driven occupied hours scheduling*

Major Problem Areas

- Inadequate temperature control systems
  - Specs must be complete and encompass all factors
- Disabled lighting occupancy sensors
  - For good reason
- Failure to commission building
  - Get what you paid for

Functional Specs

Define Owner Position

- CO2 Sensing
- Humidity Sensing
- Economizer
- Discharge Air Control
- Outside Air Control
- Fan/Pump VFDs
- Refrigeration Equip
- Chilled Water Equip
- System Communications
- Outside Air Purge
- Boilers/Operation
- Heating Water
- Demand Control
- Startup/Shutdown Optimization
- Unoccupied Hrs Oper
- Manual Override
- VAV Boxes
- Room Temp Control
- Occupancy Sensors

And more….

What's The Value?

- Significant recurring energy cost reductions
  - Example: 70,000 SF building (YMCA)
    - Two years old
    - Operating costs: $2.25/SF
    - Should be about: $1.25/SF
    - Annual savings: *$70,000*
    - Five year savings: *$350,000*
    - Ten year savings: *$700,000*

More Value

- Environmental Issues
  - Mold & mildew containment
  - Better learning atmosphere
  - Reduced power plant emissions
- Better community neighbor
- Energy conservation leader

Energy Modeling Helps

- Get a handle on energy
  - Choose architecture using modeled options
  - Choose HVAC systems based upon valid energy factors
- Get a handle on energy-efficient options
  - Use modeling to focus on key choices
  - Provide good choices for costing-out
  - Make choices using *evaluated* options

Building Energy Modeling

It's What Energy Efficiency is All About!

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